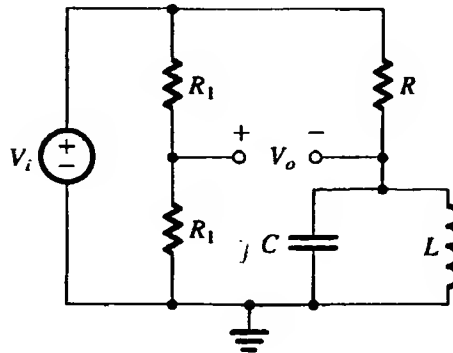Answer all questions. Use appropriate assumptions in your answers.
Open notes, calculator.

Question 1: (20 marks)

Derive the transfer function, V_o/V_{in}, of the all-pass filter below. For a given R, L, C, find frequencies at which the output undergoes a phase shift of 90° and 180° (i.e., frequencies are functions of R, L, C). Find sensitivity of the 90° frequency with respect to the inductor L.

Question 2: (20 marks)

a. Air pressure is a function of altitude is given by the following relationship:

$$Pressure = (101.3 - 0.15h^{2/3})\, kPa \quad for \quad 0<h<15,000m$$

A particular resistive pressure transducer has a sensitivity of $0.1\Omega/Pa$ with a resistance of $10K\Omega$ at sea level. Sketch the expect resistance as a function of altitude. What will be the expected resistance at 0m, 7,500m and 15,000m? Use the shunt resistance technique to linearize the transducer and find the expected resistance at those altitudes. Provide a suggested circuit that would result in an output voltage proportional to altitude using the linearized transducer. Discuss any issues that are relevant to this problem and justify your choice of circuit.
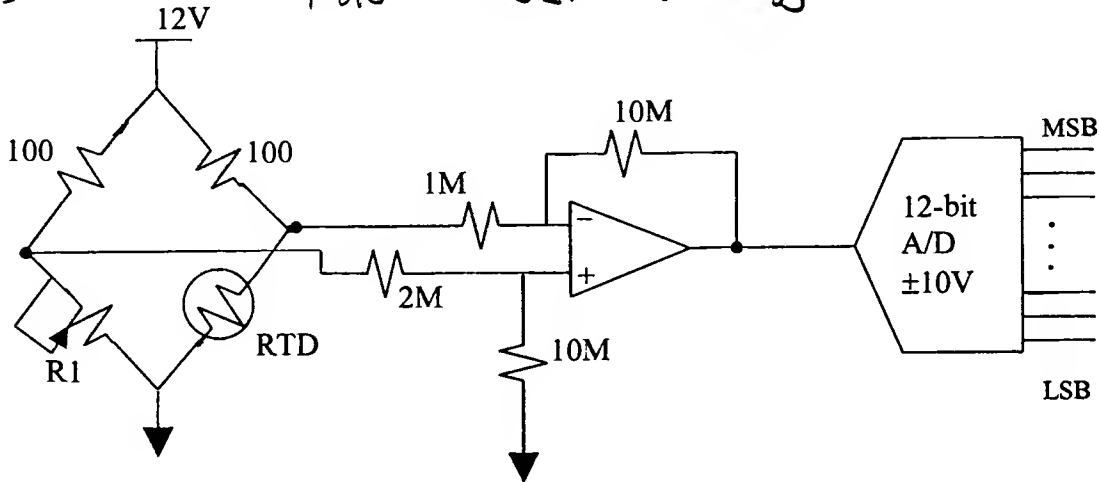
b. A controller is needed for a house attic ventilation fan. The fan is to be turned on if the attic temperature is $10^o C$ greater than the outside temperature. However, this is only to happen if the outside temperature is above $20^o C$. Design the instrumentation system, including the transducers, required to generate an on/off control signal.

X Question 3: (20 marks)

An RTD forms one arm of the Wheatstone bridge as shown in the figure below. The RTD has a resistance of 25Ω at a temperature of $0^{\circ}C$, and a thermal coefficient of resistance, $\alpha=0.003925^{\circ}C^{-1}$. The value of the variable resistance R1 must be set to 41.485Ω to balance the bridge circuit, with the RTD in thermal equilibrium with the measuring temperature.

    a. Determine the temperature of the RTD when the bridge is balanced.
    b. What is the output of the A/D converter when the temperature of the RTD is $235^{\circ}C$. (The 12-bit A/D has a range between $-10V$ to $+10V$).
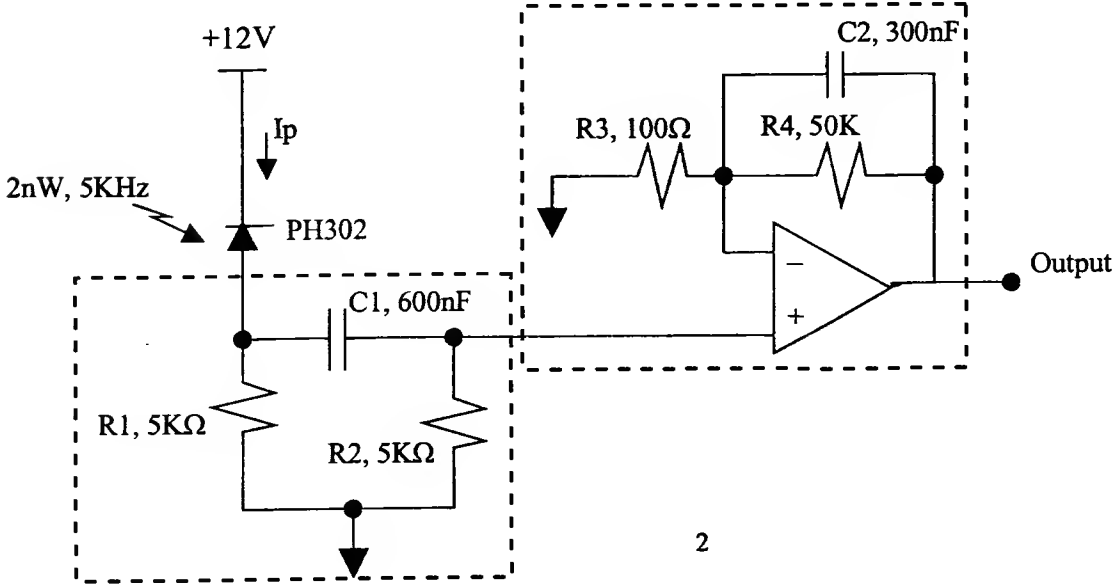
$$R(T) = R(T_0)[1+\alpha(T-T_0)]$$

? X Question 4: (20 marks)

A PH302 photodiode is used as an optical transducer in the circuit below. The photodiode has a responsivity of 0.6A of photocurrent (Ip) per watt of incident radiant power.
    a. What is the network R1C1R2?
    b. What is the network C2R3R4 and the op-amp?
    c. Determine the output signal if the input radiant power is 2nW at 5kHz.

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Question 5: (20marks)

Using appropriate design table to design a HPF with the following specifications:
- Passband ripple 1dB,
- Stopband frequency 1.5MHz,
- Passband frequency 2.5MHz,
- Stopband attenuation 30dB.

Question 6: (10 marks)

Static pressures are to be measured at 8 locations under the hood of a NASCAR race car. The pressure transducers to be used have an output span of ±1V for an input span of ±25 cm H_2O. The signals are measured and recorded on a portable DAS, which uses a 10-bit, 5V A/D converter. Pressure has to be resolved to within 0.25cm H_2O. The dynamic content of the signals is important and has a fundamental period of ~0.5s. The system has a 4MB of memory, powers all instruments, and has 10 minutes of usable battery life. Suggest an appropriate sample rate, total sample time, and signal conditioning for this application. Sketch a signal flow diagram through the measurement system.